A novel approach for closed-loop smart air purifiers using real-time monitored weather data

Ashwani Shukla
Delhi Technological University
New Delhi, India
shuklaashwani99@gmail.com

Devashish Khulbe
Delhi Technological University
New Delhi, India
devashishk96@gmail.com

Ankit Chaurasia
Delhi Technological University
New Delhi, India
ankitchaurasia21@gmail.com

Abhishek Kumar
Delhi Technological University
New Delhi, India
akbhath@gmail.com

***Abstract*—All major air purifiers available in the market work on the principle of open loop system with heavily depending on manual control. Moreover, they do not consider the changes in ambient air quality which they are purifying. This paper presents a new approach to monitor and collect the data via various sensors which contribute in determining the quality of air and simultaneously incorporating that data to be fed into the control process of air purifier mechanism. In this way, manual control of purifiers can be obviated and they can be made "smart" by automatically determining the operating intensity by sensing the surrounding air quality.**

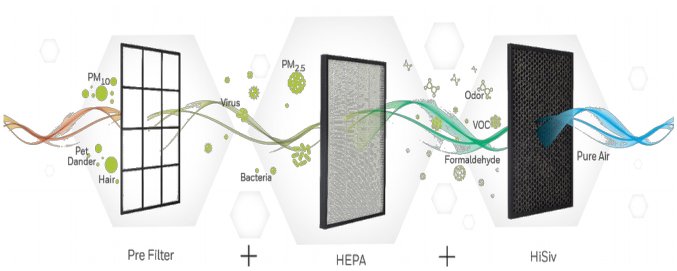
Keywords: Air quality, pollution sensors, air purifiers, closed-loop technique, on-line device operation.

I. Introduction

Air pollution is one the most crucial factors affecting the quality of life and health of increasingly urban populations; a country with a fast-growing economy based on hydrocarbons such as India is not an exception. In addition to the adverse impact of air pollution on humans, animals and plants, the presence of dust and air-borne particulate matter affect negatively the efficiency of solar panels used for power generation. In the present project, a comprehensive wireless solution is proposed for monitoring the level of harmful gases both indoor and outdoor. The proposed system enables measurement of the levels of the known harmful gases CO2, NO2 CO and CH4, dust, temperature, humidity, solar irradiance, pressure, wind-direction and wind speed. Data is collected by appropriate sensors nodes that communicate via Universal Serial Bus port (UART protocol) with a host computer that process, store and display the collected information.

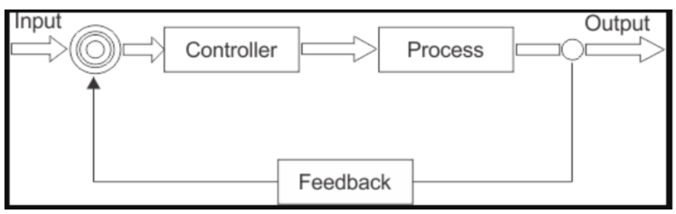
Air filters utilize fine sieves that filter particles from circulating air. As air flows into the air purifier, the finer the sieve used, the smaller the particles it traps. The accepted benchmark for air filters has been set by the High Efficiency Particulate Air (HEPA) filters, which are guaranteed to trap 99.97% of airborne particles larger than 0.3 microns. Room air conditioner filters only capture particles 10.0 microns or larger. HEPA filters remove smaller allergens like dust, smoke, chemicals, asbestos, pollen, and pet dander.

Fig. 1. Air purifying process (HEPA technique)



The major problem with almost all air-purifiers is the underlying open loop mechanism with which they work. If their operation intensity is unchanged by manual control, they continue to work on a constant speed, regardless of the air quality in their surroundings. We propose a mechanism through which their operation can be made automatic and less energy consuming by feeding them the data of ambient air quality in their control mechanism, thereby making the process closed loop.

Fig. 2. Closed-loop control process



II. Data Monitoring and Collection

A. MQ2 Gas Sensor

The MQ2 Gas Sensor module is useful for gas leakage detecting in home and industry. It can detect LPG, i-butane, propane, methane, alcohol, hydrogen and smoke. The MQ series of gas sensors use a small heater inside with an electro-chemical sensor. They are sensitive for a range of gases and are used indoors at room temperature. The output is an analog signal and can be read with an analog input of the Arduino.

B. MQ7 Gas Sensor

MQ7 is a Carbon Monoxide (CO) sensor, suitable for sensing Carbon Monoxide concentrations (Parts Per Million (PPM)) in the air. The MQ7 sensor can measure CO concentrations ranging from 20 to 2000 ppm.This sensor has a high sensitivity and fast response time. The sensor's output is an analog resistance. The drive circuit is very simple, just a voltage divider; all we need to do is power the heater coil with 5V DC or AC , add a load resistance, and connect the output to an ADC or a simple Op-Amp comparator.

C. BMP180 Barometric Pressure Sensor

BMP180 is a high-precision, low-power digital barometer. The BMP180 offers a pressure measuring rang of 300 to 1100 hPa with an accuracy down to 0.02 hPa in advanced resolution mode. It‟s based on piezo-resistive technology for high accuracy, ruggedness and long term stability. The chip only accepts 1.8V to 3.6V input voltage. However, with outer circuit added, this module becomes compatible with 3.3V and 5V.

D. DHT22

DHT22 capacitive humidity sensing digital temperature and humidity module is one that contains the compound has been calibrated digital signal output of the temperature and humidity sensors. The sensor includes a capacitive sensor wet components and a high-precision temperature measurement devices, and connected with a high-performance 8-bit micro controller.

E. Rain Sensor and LDR

The rain sensor module is an easy tool for rain detection. The module features, a rain board and the control board that is separate for more convenience, power indicator LED and an adjustable sensitivity though a potentiometer. The analog output is used in detection of drops in the amount of rainfall. Connected to 5V power supply, the LED will turn on when induction board has no rain drop, and DO output is high. When dropping a little amount water, DO output is low, the switch indicator will turn on. Brush off the water droplets, and when restored to the initial state, outputs high level.

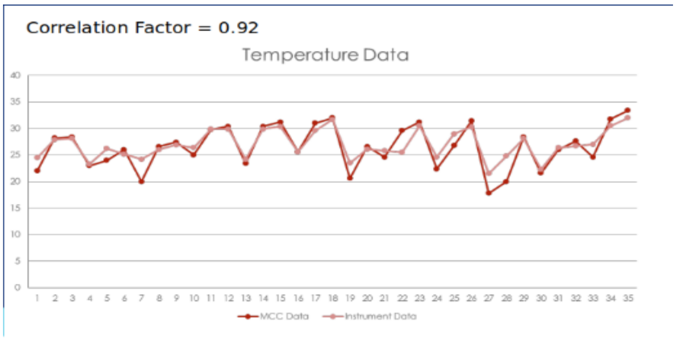
A photo resistor (or light-dependent resistor, LDR, or photo-conductive cell) is a light-controlled variable resistor. The resistance of a photo resistor decreases with increasing incident light intensity; in other words, it exhibits photo conductivity. A photo resistor is made of a high resistance semiconductor. In the dark, a photo resistor can have a resistance as high as several mega ohms (MΩ), while in the light, a photo resistor can have a resistance as low as a few hundred ohms. If incident light on a photo resistor exceeds a certain frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electrons (and their hole partners) conduct electricity, thereby lowering resistance.

III. Data Verification

We compared our real time recorded data from the sensors and the official values of AQI measured at a nearby site.

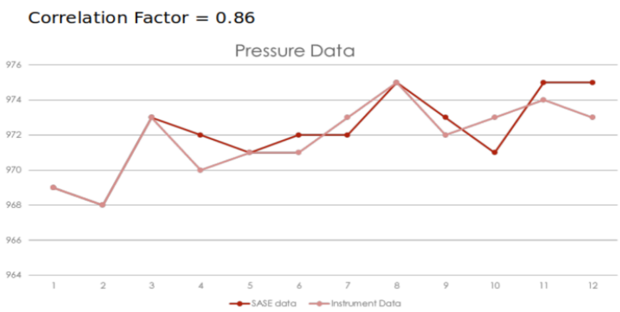
A. Temperature verification

Fig. 3. Temperature comparison



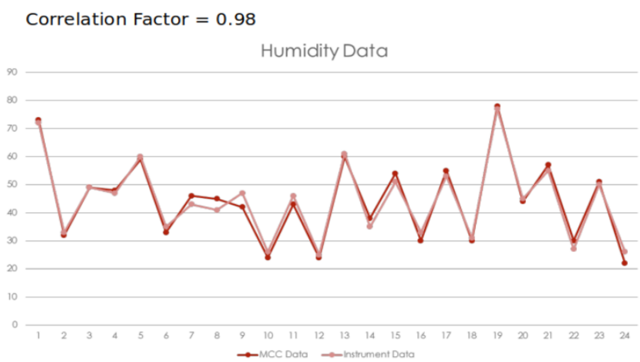
B. Pressure verification

Fig. 4. Pressure comparison



C. Humidity verification

Fig. 5. Humidity comparison



The correlation factor (k) is determined by the following formula and indicates the similarity between the two datasets as it approaches to 1.

$$k = n(\Sigma xy) - (\Sigma x)(\Sigma y) / \sqrt{[n\Sigma x^2 - (\Sigma x)^2 [n\Sigma y^2 - (\Sigma y)^2]]} \quad \ldots(1)$$

We collected the official 24 hour data for temperature, pressure and humidity from a weather monitoring facility in Rohini, New Delhi and calculated the correlation factor with our recorded data from the sensors. All three data sets gave out correlation factors > 0.85, indicating that our readings are accurate and good to use further.

IV. Controlling the Purifier process

The Pseudo code for the feedback control mechanism of the purifier is shown below. For simplicity, we have assumed that we are controlling a D.C. motor from only one parameter: the sum of the voltages (corresponding to respective pollutant particles) and resistance (corresponding to the solar irradiance).

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For each cycle:
  take readings of all sensors via serial bus;
  segregate the voltage and resistance values from temperature, humidity,
      LDR  and rain warning values;
  calculate sum of the voltage and resistance values;
  define higher and lower threshold values of motor operation;
  define higher, mid and low motor speeds for motor;
  if sum > higher threshold:
    send high speed command to motor;
  if sum < higher threshold and sum > lower threshold:
    send mid-speed command to motor;
  else:
    send low speed command to motor;
```

A. On-line sensor readings

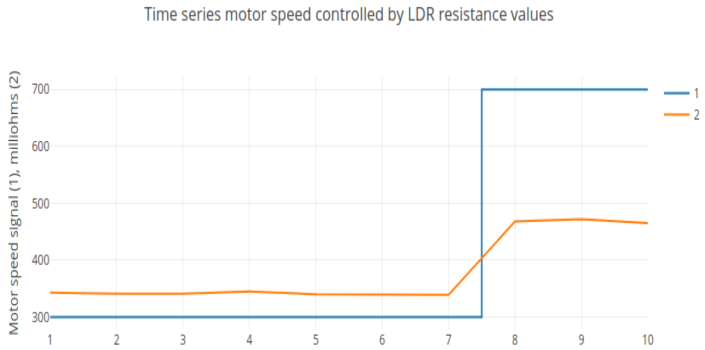
A table containing the collected voltage and resistance readings from our apparatus is shown below. Higher voltage and resistance readings correspond to higher concentrations of respective particles and irradiation in the surrounding.

TABLE I. Sensor Readings

Time Stamp (s)	Equivalent voltage/resistance readings		
	MQ2 (mV)	*MQ7 (mV)*	*LDR (resistance) (mΩ)*
1	121	732	343
2	143	701	341
3	140	701	341
4	132	710	345
5	130	707	340
6	144	718	339
7	142	718	339
8	142	720	468
9	150	721	472
10	151	726	465

For simplicity, here we have shown the motor control using only the resistance values from the LDR. The lower threshold is set at 200 milliohms and the higher threshold is set at 400 milliohms. In the below shown graph, the motor is running at the mid-speed (300 units) for the corresponding LDR readings. When the readings go past the higher threshold, high speed command (700 units) is sent to the motor.

Fig. 6. Motor control through LDR sensor readings



Conclusion and Future Scope

This paper presented an approach to develop an outdoor/indoor air quality and weather monitoring system that records and monitors air pollutants and weather parameters, and simultaneously incorporate that into making closed-loop air purifiers. In this way, manual control of purifiers can be made unnecessary and they can be made “smart” by automatically determining the operating intensity by sensing the surrounding air quality.

Further challenges include other factors like traffic and daylight for prediction of air quality and subsequent controlling of air purifiers. Also, the whole system can be made wireless and users can track the on-line status of system through GSM module. In addition to it, long time (> 7days) weather forecasting by using Machine Learning and covering larger area can be done before rolling out this product for commercial purposes.

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